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EFFECT OF THE DISPERSITY OF GLASS BATCH ON THE STRUCTURE AND PROPERTIES OF FOAM GLASS

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The effect of the dispersity of glass batch on the basic parameters of foam glass was investigated. It was found that foam glass with prescribed performance characteristics can be obtained by picking a definite combination of granulometric composition of the initial raw material and the temperature–time regime for foaming.

Key words: foam glass, foaming agent, porosity, density, strength, thermal conductivity, water absorption.

Foam glass is a rigid high-porosity material with a closed cellular structure whose performance meets the highest specifications. The structural characteristics of foam glass combine different properties making it possible to use the glass as an absolutely incombustible, biologically and chemically resistant material that retains its properties at high temperatures and humidity [1].

The properties of foam glass are regulated by using initial materials of different dispersity and changing the form and amount of foaming agent as well as by adjusting the technological parameters of the process: temperature, foaming time and firing regimes.

The temperatures and times required for foaming of glass batch containing as the foaming agent different amounts of comminuted natural marble (microcalcite) were determined in [2]. It was shown that material with the prescribed density and water absorption can be obtained by varying the foaming time and temperature as well as the concentration of the foaming agent.

It is known that the specific surface area S_{sp} of the foaming mixture plays a definite role in the formation of foam glass. The effect of the particle size of the foaming agent on the kinetics of sintering and foaming as well as on the properties of foam glass is examined in [1]. The author showed that the larger S_{sp}, the lower the sintering temperature is. Thus, if for powder with $S_{sp} = 60$ cm^2/g the sintering temperature is about 900°C, then the sintering temperature decreases to 750°C for powder with $S_{sp} = 930$ cm^2/g and 65°C for $S_{sp} = 3400$ cm^2/g. Theoretically, window glass ground to particle size corresponding to $S_{sp} = 6000$ cm^2/g can form foam even at 630°C. However, in reality its foaming temperature is higher, since below 700°C no foaming agent can form an adequate amount of gas.

Powder made from window glass and passed through a 50 μm sieve was produced to determine the effect of the dispersity of glass batch on the main characteristics of foam glass under laboratory conditions. Material with smaller particles was obtained by additional comminution of the batch in a vibratory ball mill.

A PIP 9.0 optical analyzer with measurement range 0.5 – 3000 μm was used to study the particle size distribution of the powder obtained and to calculate the specific surface area of the particles. The samples prepared for the investigations in glycerin were placed on a glass slide and covered with a cover glass. In the course of the experiment the appearance of the particles is formed in the field of a transmitted beam of the microscope and converted into a digital signal by a video camera. The particle size distribution in the experimental sample is represented, by means of processing with a computer, in the form of a diagram where the particle diameter is plotted in logarithmic coordinates (in μm) along the abscissa. The left-hand ordinate represents the integral distribution and the right-hand ordinate the differential distribution (Fig. 1).

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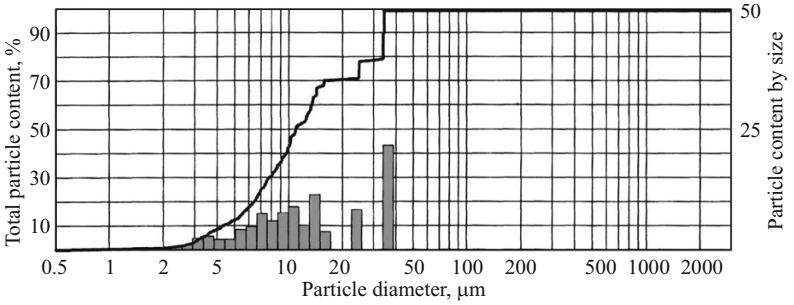

Fig. 1. Diagram of the particle diameter distribution of comminuted glass, μm.

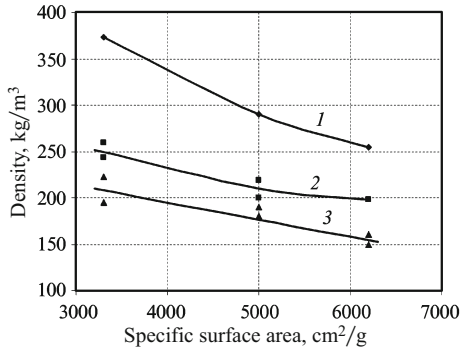

Fig. 2. Density of foam glass obtained at different temperatures versus the specific surface area of the glass batch: *1*) 725°C; *2*) 750°C; *3*) 775°C.

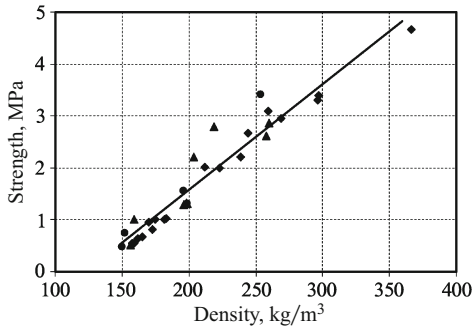

Fig. 3. Strength of foam glass in compression versus density.

The specific surface area of the samples was calculated from the measurements of the particle distribution. The specific area of comminuted glass passed through a 50 μm sieve was equal to 3300 cm^2/g (sample No. 1). After comminution in a ball mill glass powders with specific surface area equal to 5000 cm^2/g (sample No. 2) and 6200 cm^2/g (sample No. 3) were obtained by varying the milling time.

The influence of the dispersity of the glass batch on the parameters of carbonate foam glass was studied on samples prepared using the previously chosen foaming agent (microcalcite) 2.0%:

– heating from 20 to 600°C — 120 min;

– heating from 600°C to the temperature of the experiment at the rate 5 K/min;

– soaking at the experimental temperature;

– cooling from the experimental temperature to 600°C at the rate 5 K/min;

– annealing of the foam glass from 600°C to 200°C at the rate 1 K/min.

The experimental curves of the density of the foam-glass samples obtained by foaming during 45 min at different temperatures versus the specific surface area S_{sp} of the initial glass batch are presented in Fig. 2. Evidently, the density of the foam glass decreases with increasing S_{sp} (particle size decreases). The dispersity of the batch is more influential at low foaming temperatures.

An important property of cellular heat-insulation materials is the mechanical strength. The results obtained for the strength in compression of samples of foam glass made from glass batches with different dispersity are presented in Fig. 3.

As one can see from the plot, it was not possible to follow the direct dependence of the strength on the dispersity: the experimental data are satisfactorily described by a linear function of strength verses density.

The thermal conductivity of the material is largely determined by its structure. In porous bodies heat is transferred through the solid matter and through voids containing gases. Since gases are poor heat conductors, the insulation capacity of the material will be all the higher, the greater its porosity. But heat transfer inside pores decreases with decreasing pore diameter.

For construction-grade foam glass the following empirical relation expresses the linear dependence of the thermal conductivity on the bulk density [3]:

$$\lambda_{+25} = 0.000213\rho + 0.0191,$$

where λ_{+25} is the thermal conductivity (in W/(m · K)) at temperature 25°C and ρ is the density (in kg/m^3).

The experimental data on the thermal conductivity and density of the samples of foam glass made from glass batch with different dispersity and different temperature–time regimes are presented in Fig. 4. The data are in complete accord with the linear dependence constructed using the relation given above.

As follows from the data in Figs. 2 – 4, the dispersity of the batch made from comminuted glass and the temperature–time conditions for obtaining foam glass influence the

TABLE 1. Characteristics of Foam Glass

Index	Foam glass index at S_{sp}, cm^2/g, and foaming temperature t, °C								
	3300			5000			6200		
	775	750	725	775	750	725	775	750	725
Density, kg/m^3	220	260	370	200	220	300	150	200	250
Total porosity, %	91.0	89.5	85.0	92.0	91.0	88.0	94.0	92.0	90.0
Open porosity (water absorption), %	10.0	4.5	2.0	12.0	5.8	3.0	18.0	6.5	4.0
Closed-porosity fraction, %	89.0	95.0	97.6	87.0	93.4	96.6	80.9	92.9	95.6

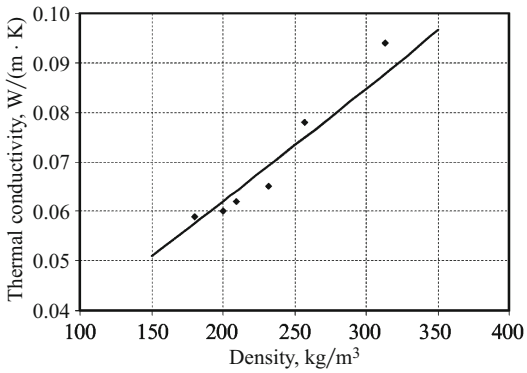

Fig. 4. Thermal conductivity of foam glass versus density.

thermophysical and mechanical characteristics of the samples via the density.

The density of foam glass depends on its porosity. The total porosity, which includes the open and closed porosities, is calculated from the relation $P = 1 - \rho/\rho_g$, where ρ is the density of the foam glass and ρ_g is the density of the initial glass [4, 5]. Open pores communicate with the surface, participate in filtration processes and determine the capacity of the material to absorb water. For this reason the open porosity can be determined from the volumetric water absorption of the material. In the course of the investigations an attempt was made to analyze the pore structure of foam glass obtained from batch with different dispersity at different foaming temperatures (Table 1).

It is evident from the results presented in Table 1 that for all values of S_{sp} considered the total porosity increases with increasing foaming temperature and, correspondingly, the density of the samples decreases. The minimum bulk density of foam glass is obtained with the maximum dispersity of the batch and foaming temperature. However, in this case the increment to the porosity is mainly due to the formation of open pores and results in elevated water absorption. Foam glass with high density, as a rule, has low water absorption and is obtained at lower foaming temperatures.

A cellular material with a uniform structure and predominately small pores (100 – 500 μm) is obtained by means of heat treatment of glass batch with different milling fineness (from 3300 to 6200 cm^2/g) at 750°C for 45 min (Fig. 5). The density of the foam glass ranges from 260 to 200 kg/m^3.

In summary, the data presented in this work show that the mechanical and thermophysical properties of foam glass are linear functions of its density. In turn, the density of the cellular material is determined by the milling fineness of the raw material and the temperature–time regimes of the foaming process. For this reason material with the prescribed set of performance properties can be obtained by optimizing the fabrication conditions.

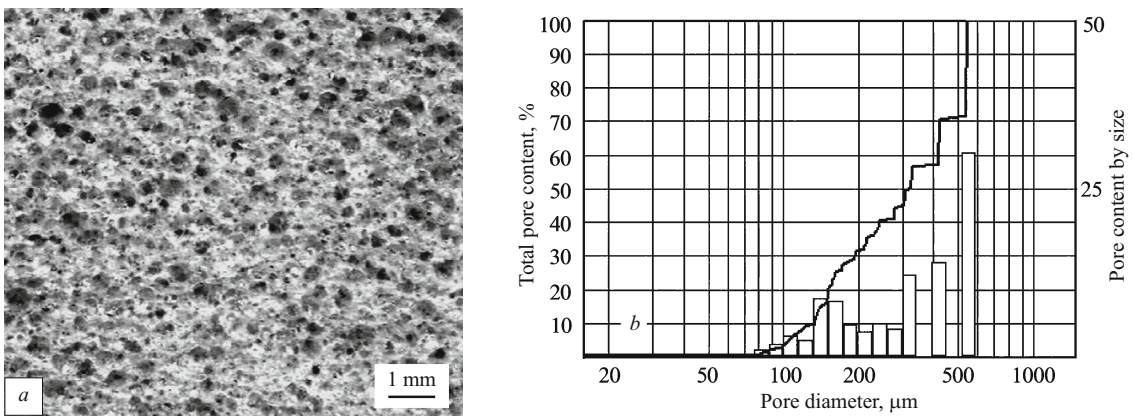

Fig. 5. Microstructure of foam glass (*a*) and pore size distribution (*b*).

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